# NETWORKING COMMUNICATIONS INTEGRATION OF SUBSTATION PROTECTION AND CONTROL WITH LARGE-SCALE WIND FARM CONTROL

**Marcus D.W. Steel**
Power Engineering Group, Hydro Tasmania Consulting
Hobart, Tasmania. Australia
*Email: {firstname.surname@hydro.com.au}*

**Abstract**
The introduction of protection ethernet-based signalling in Australia presented some technical hurdles owing to the perceived variable nature of an ethernet network, and consequently the difficulty to predict its performance. Protection ethernet-based signalling (ie IEC 61850) displaced the hardwired protection schemes that are the tradition. Integration of protection ethernet-based signalling into a large scale windfarm substation such as at Woolnorth has significant implications for flexibility, disturbance recording, maintainability and commissioning tests, because the characteristics of ethernet-based signalling are different from those of conventional hardwiring. In addition the transmission network constraints lead to a runback scheme, thereby potentially increasing the dimensions of the technical issues. This paper examines the technical issues associated with the integration of protection ethernet-based signalling within a large scale windfarm in the presence of transmission network constraints.

**Keywords**: LAN, GOOSE, VLAN, RSTP, TCP, UDP, IP, SCADA, NTP, SNTP.

## 1 Introduction

As a result of standardisation initiatives to minimise the emission of greenhouse gases, and the introduction of a Mandatory Renewable Energy Target (MRET) in Australia, an increasing proportion of electricity is generated from renewable sources. Wind resource monitoring studies have revealed that Tasmania offers one of the best wind resources in the world. Having developed the major part of Tasmania's available hydro resources, Hydro Tasmania has now turned to wind generation. The Woolnorth Wind Farm project is exceptional in many ways. Located on the remote northern tip of the West Coast of Tasmania, construction of the second 65 MW stage of the Woolnorth Wind Farm represents an exciting step and will follow the establishment of a 110kV transmission line.

The first 110/22kV substation at Woolnorth Wind Farm is expected to be commissioned in late 2003. The substation known, as ‘Woolnorth’, will create an electrical connection with the Tasmanian Electricity Transmission System, and this is expected to provide extra electrical energy to participate, not just in the Tasmanian market, but also in the Australian national electricity market. The networking communications at Woolnorth substation will integrate substation protection and control with large-scale wind farm control.

The technical issues discussed in this paper include:

- Networking system capability;
- Capability of Ethernet switch technology to meet protection criteria;
- Impacts of TCP/UDP and IP on networking system requirements;
- Interaction between substation and wind farm control systems.

## 2 Substation Protection Networking System

The networking communications equipment used in substation LANs (Local Area Networks) for protection signalling will have:

- A safety integrity level (IEC 61508) identical to the connected protection relays,
- A level of reliability and robustness (IEEE P1613) equivalent to the connected protection relays,
- Performance that equals or betters the performance of hardwiring individual electro-mechanical connections between protection relays.

The model for asynchronous multicast communications of substation events has been established by UCA in GOOSE messages [1]. GOOSE messages provide the capability to convey a protection relay’s digital outputs status to other protection relays connected to the same LAN. In IEC 61850, the Generic Substation State Event (GSSE) represents the GOOSE message as defined in UCA Version 2.

### *2.1 RuggedSwitch Network Devices*

The RuggedSwitch product family of network devices comply with an extensive list of IEC and IEEE standards that are relevant to protection relays in harsh EMI environments. The network performance of RuggedSwitch network devices combines raw throughput with a collision-less mode of operation. The packaging of network ports in RuggedSwitch Ethernet switches is very compatible with the strategy for network architecture in large scale windfarms.

### *2.2 GE UR & SEL 421 Protection Relays*

In embarking on an period of large scale windfarm construction, the selection criteria for the protection relays included support for network communications using UCA2 GOOSE/IEC 61850 GSSE. A demonstration of UCA2 GOOSE messaging between a

GE UR and SEL 421 protection relay was carried out in Tasmania before proceeding with a protection design that would implement circuit breaker failure using GOOSE messages [2]. The design of oscillography recording in the protection relays is enhanced to trigger waveform capture site-wide using GOOSE messages. When the transmission network constrains windfarm generation, the automation capability in the SEL 421 relay at the windfarm 110kV connection point could enable GOOSE messages to be sent to GE UR relays that can disconnect blocks of wind turbine generators.

## 3 Philosophy of Network Operation

The protection & control network in the windfarm and substation at Woolnorth is designed to operate with a 100Mbps backbone. In addition to the backbone, the Ethernet switch ports connected to the personal computers and GPS time receiver in the local control systems will operate at 100Mbps. The protection relays, wind turbine generator controllers and SCADA remote terminal unit will all operate at 10Mbps. Providing a firewall to the corporate IT system is a network appliance with 100Mbps on a LAN port and 10Mbps on the WAN port. A firewall is also provide to the Warranty, Operations & Maintenance provider's IT system using a network appliance with 100Mbps on a LAN port and 10Mbps on the WAN port. Two separate areas of redundancy are being developed:

- Substation Protection Networking System,
- Windfarm Control Networking System.

A rapid spanning tree protocol (RSTP) application is designed to rapidly reconfigure the network for loss of a redundant path. The RSTP path cost can be used to establish the topology of the network exactly as the designer intends. The redundant ethernet switches for the substation protection network detect 'loss of link signal' from each other and GE UR/SEL 421 relays, and switch to the backup port. The rings of Ethernet switches for the windfarm control network detect a 'loss of link signal' signal and unblocks the alternate path from the wind turbine generator controller to the windfarm control system.

In line with real-time design philosophy for protection signalling, the traffic classification on Substation Protection Networking System from GE UR & SEL 421 relays is configured to enforce high priority using IEEE 802.1Q whereas signal scanning/polling of the wind turbine generator (WTG) controllers is at low priority. This means that applications on the IT systems could load the Networking System beyond the specific capacity required for substation protection and control and windfarm control. To prevent this operation causing significant problems, traffic on the Ethernet switch ports connected to the IT system firewalls will be managed as a logically separate VLAN. This also allows for cyber ring-fencing of the substation and windfarm protection and control networking system while retaining internetworking capability and suitable performance for IT system applications.

### *3.1 Time Synchronisation and Networking*

The networking systems comprise a number of Ethernet switches and media converters, and respond to the loss of a link in a manner that allows an OPC/SNMP server to monitor network data from the switches easily as well as receiving alarms. Another feature that has an impact is time synchronisation, which is designed to use SNTP (Simple Network Time Protocol) for obtaining time from an NTP time server – a Truetime GPS clock. The Ethernet switches for operation in the Woolnorth networking system were tested for connectivity with a Truetime GPS time receiver. Time synchronisation is particularly important during protection post-fault analysis, as conceivably there could be network topology changes coincident with commissioning activities or power system fault conditions.

### *3.2 Maintenance of Networking*

The RuggedSwitch maintains a number of volatile and non-volatile files. These files can aid in the resolution of problems and serve as a useful gauge of the switches health. The design of the networking systems allows transfer of the log files from the Woolnorth networking system to the corporate IT systems. A principle of secure collaboration in maintaining the Woolnorth networking systems has been the basis of network administration work practices.

Port mirroring is a RuggedSwitch tool in which all traffic on a designated port is copied (mirrored) to a target port. If a protocol analyser is attached to the mirror port, the traffic stream on any designated port is made available for analysis. An analyser not only captures the raw Ethernet frame, but also decodes most messages contained within the frames so providing maintainers with extensive debug capabilities.

## 4 TCP/UDP and IP

In the Substation Protection Network System, the choice of TCP/IP in protection relays is of major concern with its preconceived design to hang on to client connections. This becomes a major issue when conventional clients, such as personal computers and SCADA remote terminal units, re-establish connections with a protection relay that has a small maximum number of connections. The issue here is associated with maintaining protection systems availability and reserving a sufficient number of unused connections to satisfy remote monitoring of the GE UR relays by SCADA during normal and emergency circumstances. In order to maintain the required minimum connections, the TCP ports for the web server http protocol, UCA/MMS protocol and Modbus protocol feature are all blocked from direct access by the corporate IT systems. In the case of the SEL 421, the remote monitoring by SCADA using the DNP3 protocol over TCP/IP or UDP/IP was not possible at the time of commissioning.

Multicast applications running over the UDP/IP protocol, such as Internet telephony, would limit the ability of the Ethernet switches to filter the MAC destination address in Ethernet frames. The speed at which UDP sends data is only constrained by the rate at which the application program generates data, the capabilities of the source processor and the access bandwidth to the network system. Even so, UDP is a better fit for some applications, for example, NTP & Simple Network Time Protocol (SNTP).

There is information for the Internet community in RFC's on efficient IP address allocation. The administration of IP addresses will vary with:

- Number of hosts,
- Upstream vendor eg. corporate IT,
- Virtual Local Area Network aggregation.

Fixed IP addresses, rather than allocation by DHCP, is the policy for all hosts in the networking systems.

## 5 Control System Architecture

Integration of substation and wind farm control has the potential to consolidate control, monitoring and collection of information. For inter & intra control system traffic, isolation from the networking systems for protection & control may be beneficial. However, in a small system the consequence may be more costly as a specific communications system (eg. network interface cards and Ethernet switches) would be required. An increase in network traffic could exert great influence on the monitoring process of the wind farm, and the ability to control wind farm output with the required voltage regulation and the ability to control circuit breakers in the substation.

## 6 Conclusions

This paper has presented an overview of technical issues associated with the networking communications integration of substation protection and control with large-scale wind farm control. The specific interaction between protection and control is also discussed. The solutions discussed in this paper are focused on a specific combination of protection and control technologies.

In summary, management of key networking integration issues is feasible but to achieve it some restriction to the open access from the corporate IT system and prioritisation of traffic from protection relays to allow performance of circuit breaker failure is required.

**Reference:**


1. M. Adamiak, D. Baigent, S. Evans, "Practical Consideration in Application of UCA GOOSE", *Georgia Tech Relay Conference 2000*.
2. A.P. Apostolov, "Application of High Speed Peer-to-Peer Communications for Protection and Control", *34-105 Cigre 2002.*


**Footnote:** The Woolnorth protection and control network was commissioned in March 2004. A second protection and control network was commissioned at the Cathedral Rocks windfarm in May 2005.